RECOGNIZING HERBICIDE ACTION & INJURY

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RECOGNIZING HERBICIDE ACTION & INJURY

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Introduction

Herbicides have been a major tool in vegetation management for the last 35 years. During this time, a variety of products has been used in field crops, vegetable production, rangeland maintenance, forest management, parks and recreational areas and in industrial, urban and aquatic sites. While herbicides for long-term total vegetation control may be used in some instances, they are most commonly used in a selective manner. That is, specific herbicides are chosen to control undesirable species without significantly affecting the crop. Herbicides registered for the control of weeds in specific crops have proven their ability to do a specific job. The specific uses of the herbicides and the guidelines required to ensure safe application are outlined on the label and should be strictly followed. However, during field use, there will be occasions when drift, improper timing, improper rate or unusual weather conditions result in undesirable effects on the crops sprayed or on neighboring crops.

Diagnosis of herbicide injury/damage and the reasons for its occurrence requires a knowledge of the symptoms produced by the herbicides involved, and of their mode of action and behavior and fate in soils. In addition, the different modes of action of herbicides create problems in determining whether a particular herbicide is actually controlling the weeds in its prescribed manner.

This publication is intended to aid those who may be required to recognize herbicide action and injury in the field and to assist in the understanding of herbicide action. In addition, it provides applicators with information that, if used as intended, will prevent injury caused by herbicides.

Some Common Causes of Herbicide Injury

Causes	Field Symptoms	Preventive Steps
Herbicide related		
1. Normal consequence of application	Lightening of crop color after application, a normal consequence of the application of some herbicides.	None. Accept the fact that some herbicides have harmless side effects.
2. Higher dosages	General crop injury.	Apply **only** at recommended dosages.
3. Spray and/or vapor drift	The vegetation of a field or garden is affected with the heaviest injury closest to the source of drift.	Use low or nonvolatile herbicides. Use low pressure, high water volumes and drift control devices. Apply under calm conditions.
4. Additives	Crop yellowing, loss of vigor, stunting.	Use additives **only where herbicide labels so instruct.**
5. Incompatible mixes	Crop injury, lack of weed control.	Use **only** registered and recommended mixtures.
6. Spray contamination	Crop injury during first few passes or portion of the field by a herbicide not being applied at the time.	Flush and clean spray tanks thoroughly after every operation and particularly before use on a crop sensitive to the previously-used herbicide.
	General crop injury.	Avoid contamination of spray materials. Avoid use of contaminated water from ponds, dugouts and ditches for spraying.
7. Residue in soil	Crop fails to germinate or grow adequately.	Check and follow label instructions regarding succeeding crops.
	Crop fails to grow normally when soil, sand, peat moss or manure are added.	Check for herbicide residue in added component (trash, soil, manure) before movement to intended site.

Causes	Field Symptoms	Preventive Steps
Application equipment, and/or application technique related		
1. Improper equipment	Strip injury due to worn nozzles, non-uniform nozzles, or end nozzles overlapping.	Proper choice, adjustment, maintenance and calibration of spray equipment.
2. Inadequate mixing	Crop injury near sprayer starting point.	Add water to tank before adding herbicide. Mix thoroughly.
3. Improper technique	Spot injury at sprayer turning points.	Traverse length of field during application rather than applying in a circular manner. Shut down spray system when turning at the end of rows.
	Banded injury patterns.	Avoid overlapping of spray runs.
Crop related		
1. Growth stage	General crop injury.	Apply only at recommended growth stages.
2. Susceptible varieties	General crop injury.	Match herbicide with tolerant variety.
Weather related		
1. Frost	General yellowing, loss of vigor and leaf tip browning due to combination of herbicide and frost stress.	Where possible avoid spraying soon after or before a frost.
2. Drought	General yellowing, wilting and loss of vigor due to combination of herbicide and moisture stress.	Only use herbicides to which crop has a high tolerance; use the maximum recommended water volume; do not spray during the heat of the day.
3. Cool wet conditions	Poor emergence, general yellowing, wilting and loss of vigor.	Only use herbicides to which crop is tolerant.

Typical Herbicide Injury Symptoms

Herbicide injury in a field often displays a distinct pattern. Although herbicide effects on plants vary, related compounds usually cause plants to show a characteristic group of symptoms. Herbicides may affect one or more plant organs simultaneously thus resulting in a number of typical injury symptoms on leaves, stems, flowers, fruits and roots.

Injury Symptoms on Leaves

1. Feathering of leaves: This symptom is typical of leaf malformations induced by translocated growth-hormone herbicides such as 2,4-D, MCPA, dicamba and sometimes glyphosate (Figures 82 and 255).
2. Fiddlenecking: This pronounced symptom occurs in the young growing points of plants. An upward curling of older leaves is also obvious. Such symptoms are produced by growth-hormone herbicides such as dicamba and picloram (Figures 21 and 122).
3. Cupping of leaves: A distinct cupping (usually upward) is typical of injury from growth-hormone herbicides such as 2,4-D, MCPA and dicamba (Figure 81).
4. Crinkling of leaves: In the case of grass species like corn, leaves fail to emerge from the sheath normally, and the plants remain in a stunted condition with twisted, and crinkled leaves. This symptom can be caused by thiocarbamate herbicides, such as EPTC and Triallate (Figure 165).
5. Leaf rolling: Failure of leaves to unroll normally is a typical injury symptom on grasses caused by dinitroaniline compounds such as trifluralin (Figure 55).
6. Chlorosis: One of the more typical injury symptoms of herbicides is a loss of chlorophyll from leaf tissues resulting in yellowing in many patterns.

   Meristematic chlorosis: Chlorosis, which initially occurs in the meristematic regions (growing points) of plants, is typical of translocated herbicides such as amitrole, glyphosate, chlorsulfuron, sethoxydim and fluazifop butyl. The chlorotic areas may appear almost yellow, white or pinkish in color (Figures 195, 261 and 263).

   Veinal chlorosis: Yellowing in the veins of leaves, commonly called veinal chlorosis, usually results from root uptake of some herbicides. This symptom is typical of the uracil and urea herbicides such as bromacil, terbacil and diuron (Figure 214).

   Interveinal chlorosis: A yellowing of tissues between the veins of leaves. This typical injury is caused by the triazine herbicides e.g. atrazine, and results from root uptake of the herbicide (Figures 181 and 200).

Marginal chlorosis: This symptom occurs as a narrow yellow band almost entirely around the leaf margin. It is sometimes called the "halo effect". This symptom can occur from foliar uptake of triazine herbicides such as cyanazine and metribuzin (Figures 178 and 183).

Mottling: This refers to a chlorosis which occurs randomly on the leaf. Parts of the leaf remain green whereas others become chlorotic. Injury occurs only on leaves that came in contact with the spray; new leaves which develop afterwards appear normal. Contact-type herbicides such as diquat, paraquat and bromoxynil can cause such symptoms (Figures 37 and 38).

7. Necrosis: Death of isolated tissues. It usually follows chlorosis.

Marginal necrosis: Often develops on the older leaves after they have exhibited a chlorotic condition. An overdose of a herbicide such as metribuzin can cause such symptoms (Figures 139 and 178).

Flecking: Necrosis occurring in small spots scattered through the leaf is often called flecking. This is caused by contact-type herbicides such as paraquat and bromoxynil (Figure 37).

Injury symptoms on Stems

1. Epinasty: This term describes a bending and/or twisting that occurs in either the stem or petioles of plants. The response often occurs within a few hours after exposure to a herbicide. Growth-hormone herbicides such as the phenoxys (2,4-D, MCPA), benzoics (dicamba) and pyridinecarboxylic acids (clopyralid, picloram) cause such symptoms (Figures 15, 16, 81 and 118).
2. Abnormal Stem Elongation: Stem elongation of broadleaved plants may be enhanced (at low concentrations) or inhibited (at high concentrations) by growth-hormone herbicides such as 2,4-D, MCPA, dicamba and picloram (Figure 111).
3. Stem Cracking: Stems become brittle and may break off in heavy winds. Stems crack near soil level. Symptoms are typical of injury from picloram (Figure 124).
4. Adventitious Root Formation: Growth-hormone herbicides such as 2,4-D, MCPA, dicamba and picloram can induce formation of adventitious roots at the base of stems of broadleaved plants (Figures 14 and 83).
5. Stem Swelling: Swelling of coleoptiles, hypocotyl and stem can be caused by herbicides such as EPTC, triallate, trifluralin and the growth-hormone herbicides (Figures 52 and 124).

Injury Symptoms on Flowers and Inflorescences

Herbicide injury may result in changes in size, shape or arrangement of various parts of the flower. Such effects are usually caused by growth-hormone herbicides such as 2,4-D, dicamba and picloram (Figures 20, 91 and 127).

Injury to cereals from growth-hormone herbicides may result in abnormalities of the inflorescence such as:

(1) Branched ears
(2) Ears with multiple spikelets
(3) Tweaked ears in which some spikelets are missing
(4) Incomplete heading (the ear remains partly or completely enclosed in the leaf)
(5) Ears with opposite instead of alternating spikelets along the rachis.

Delay in flowering and heading due to herbicide injury is common. Herbicides causing foliage injury may also cause delay in flowering and heading.

Injury Symptoms on Fruits

Herbicide injury symptoms on fruits may include changes in their shape, size and appearance (Figures 94, 95 and 96).

Injury Symptoms on Roots

Examination of plant roots can provide further clues to the cause of injury. Some herbicides such as EPTC, chlorsulfuron and trifluralin are effective inhibitors of root growth. The development of primary and/or lateral roots is inhibited and those that do develop are thickened and short. Severe root inhibition caused by various herbicides usually leads to stunting of plants. Growth-hormone herbicides may cause swelling of roots in some plants. (Figures 56, 57, 83, 155 and 157).

Difficulties Encountered in Recognizing Injury Symptoms

Recognizing herbicide injury symptoms usually is not straightforward and could be confusing. Some causes of confusion are:

1. Similarity of symptoms within herbicide groups

Herbicides within a particular group, for example the phenoxys, the triazines, the ureas, often show similar injury symptoms. Therefore, on the basis of symptoms alone it would be impossible to distinguish between 2,4-D and MCPA (phenoxys) or cyanazine and metribuzin (triazines).

2. Similarity of symptoms between herbicide groups

Different groups of herbicides exhibit rather similar symptoms. For example, 2,4-D, dicamba and picloram belong to different groups of herbicides yet cause similar symptoms. Similarly, in cereals the symptoms caused by triazines (cyanazine, metribuzin) and ureas (linuron) are very similar at the advanced stage of growth.

3. Range of symptoms produced by a herbicide

Injury symptoms caused by a herbicide may vary considerably with the dose applied. For example, crops affected by triazine herbicides show a range of symptoms (slight chlorosis to extensive chlorosis and necrosis) with an increase in dose. In such cases injury to a crop cannot be fully expressed by a single photograph.

4. Parallel symptoms not produced by herbicides

These may be caused by:

(a) Other pesticides: Although not so common, certain herbicides and insecticides may cause similar symptoms. For example, an overdose of dimethoate (CYGON) may cause foliar injury in broadleaved plants similar to bromacil injury.

(b) Environmental factors: Since plants are seldom grown in conditions where all life-supporting factors such as soil moisture, nutrients, light and temperature are ideal, an imbalance may induce stress which results in visible symptoms. Therefore, herbicide damage sometimes can be confused with nutrient deficiency symptoms, frost, hail and wind damage, drought injury and injury from liquid fertilizers.

(c) Plant diseases and insect damage: Many fungal, bacterial and viral infections, as well as insects, can produce plant disorders similar to those produced by herbicides. Examples of such parallel symptoms are depicted in photographs in this book.

Diagnosis of Herbicide Injury/Damage

Making an accurate diagnosis of herbicide injury is often difficult if an investigator looks at specimens of dying plants. For this reason, the investigator should actually view the affected crop as soon as possible after the damage is reported and should consider the following points:

1. Do not make snap judgements:
   It is important to gather all the possible evidence (plant and/or soil specimens, photographs) and pertinent information before drawing conclusions.

2. Ask a lot of questions pertinent to:
   a. planting details, such as date of planting, variety of crop, seed treatments, and depth of seeding
   b. spraying details, such as chemical(s) sprayed, date of spraying and nozzle, speed and pressure used
   c. stage of crop at the time of spraying
   d. weather conditions before and after spraying
   e. soil conditions.

3. Look for patterns such as:
   a. condition of untreated field
   b. symptoms on susceptible weeds
   c. symptoms of disease, insect, wind, hail damage
   d. injury pattern (strips, elevated areas, low lying areas, ends of the field, drift patterns).

4. Watch for look-alike symptoms; looks can be deceiving. These may include:
   a. nutrient deficiency
   b. fertilizer burns (anhydrous ammonia)
   c. insect or disease damage
   d. weather related injury
   e. air pollutant injury.

Chemical Damage Diagnostic and Extension Services

The Alberta Environmental Centre in Vegreville provides a chemical damage diagnostic and a herbicide residue (carry-over) detection service. These advisory and extension services are provided to agricultural producers and homeowners through the field staff of Alberta Agriculture (district agriculturists, agricultural fieldmen) and Alberta Environment (regional biologists) who act as field investigators. The field investigators, upon receiving a herbicide injury complaint, are required to visit the affected area and record their observations on a chemical damage investigation report form. Duly completed report forms along with proper soil, plant and/or water specimens are submitted to the Alberta Environmental Centre for diagnosis. At the centre, diagnosis is conducted through visual examinations and by confirming the presence of suspected chemicals through residue analysis of plant, soil and/or water specimens. Further information about the chemical damage diagnostic service can be obtained by contacting the local office of the district agriculturist, agricultural fieldman, regional biologist or the Alberta Environmental Centre (Plant Sciences), Vegreville, Alberta T0B 4L0, Phone 632-6761, ext. 283.

Common and Trade Names of Herbicides Cited

Common Name	Some Trade Names
Amitrole	Amitrole, Amitrol-T, Cytrol
Asulam	Asulox F
Atrazine	Aatrex, Primatol
Barban	Carbyne, Wypout
Bromacil	Hyvar X, Hyvar X-L, Calmix
Bromoxynil	Brominal M, Buctril M, Sabre, Torch
Chlorsulfuron	Glean
Clopyralid	Lontrel
Cyanazine	Bladex, Blagal
Dalapon	Dalapon, Basfapon
Dicamba	Banvel, Killex, Dyvel, Dycleer, Target
Diclofop methyl	Hoe-grass, Hoe-grass 284, Hoe-grass II
Difenzoquat	Avenge, Avenge 200C
Diquat	Reglone, Reglone A
2,4-D	Numerous trade names of salt, amine and ester formulations and of commercial mixtures with other herbicides
2,4-DB	Embutox E, Butyric 400, Cobutox 400
Flamprop methyl	Mataven
Fluazifop butyl	Fusilade
Glyphosate	Roundup
Linuron	Lorox L, Linuron 50 W, Afolan F
MCPA	Numerous trade names of salt, amine and ester formulations and of commercial mixtures with other herbicides
MCPB	Tropotox
Mecoprop	Compitox, Mecoturf, Mecoprop 300
Metribuzin	Lexone, Sencor
Metsulfuron methyl	Ally
Paraquat	Gramoxone, Sweep
Picloram	Tordon 22K, Tordon 10K, Tordon 101, Tordon 202C
Propanil	Stampede, Stampede CM
Sethoxydim	Poast
Simazine	Princep, Simadex, Simmaprim
TCA	Sodium TCA
Terbacil	Sinbar
Triallate	Avadex BW
Trifluralin	Treflan, Rival, Heritage

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I. ALIPHATICS

TCA and Dalapon

General uses

Control and suppression of annual grasses (e.g. green foxtail and barnyard grass) and perennial grasses (e.g. quack grass) in crop and noncrop lands. Some of the tolerant crops include flax, canola, potatoes, peas, sugarbeets, oats, barley, asparagus, cabbage, cauliflower and raspberries.

Symptoms in plants

Growth inhibition, leaf chlorosis and growth abnormalities at root and shoot tips. Rapid foliar necrosis and contact injury may occur from TCA or with high concentrations of dalapon. Increased tillering in grasses is a common response.

Behavior and fate in plants

Readily absorbed by roots and shoots. Dalapon is readily translocated in phloem and xylem and moves from one system to the other. TCA transported only in the xylem. Both compounds accumulate in young tissues. Interfere with growing-point activity in roots and shoots. Primary actions are change in protein structures and alteration of cell membrane permeability. Very resistant to degradation by plants.

Behavior and fate in soil

Both compounds leach readily in soil. Broken down rapidly and completely by microorganisms. Average persistence in soil at the recommended rates is three to ten weeks.

Effect on Weeds

Figures 1 and 2.

Lightening of green coloration is the first noticeable effect of TCA or dalapon on green foxtail. Browning of the leaf tips, growth retardation, and eventual death of the grass follow.

Figure 1

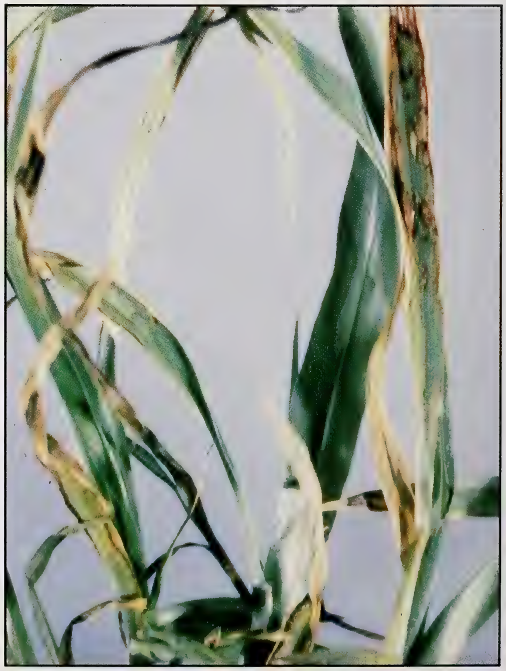

Figure 2

Figure 3

Crop Injury

Figure 3.

Effects on crops are similar to those on green foxtail if higher rates are used. In addition, on crops such as barley increased tillering can result.

Parallel Symptoms

Figures 4 and 5.

Leaf tip yellowing and browning in barley caused by net blotch may resemble TCA or dalapon injury.

Figure 4

Figure 5

II. AMIDES

Propanil

General uses

A very diverse group which also includes herbicides less commonly used in the Prairie provinces such as alachlor (LASSO), metolachlor (DUAL), and pronamide (KERB). Propanil, alone and in mixture with other herbicides, is used for control of annual grassy (green foxtail) and broadleaved weeds in wheat, barley, oats and flax.

Symptoms in plants

Initial injury to plants from foliar-applied propanil is restricted to the leaves where it causes either localized or general chlorosis followed by necrosis. Later inhibition of growth in other parts of the plant occurs probably as a result of secondary effects.

Behavior and fate in plants

Readily absorbed by leaves but translocation from treated leaves is limited. Inhibits photosynthesis and respiration. Readily degraded to nontoxic compounds by tolerant crop plants.

Behavior and fate in soil

Broken down quite rapidly by soil organisms. The average persistence in soil at recommended rates is three to seven days under warm moist conditions.

Figure 6

Effect on Weeds

Figures 6 and 7.

Treated weeds susceptible to propanil wilt one to three days after application. This is followed by yellowing of the leaf tips and margins and, within seven to ten days, browning of the entire plant.

Figure 7

Figure 8

Figure 8.

Late applications can result in the browning of some leaf tips and the lower leaves, but weed control will not be satisfactory since new leaf development will continue.

Propanil

Crop Injury

Figures 9 and 10.

A normal consequence of propanil application to wheat and barley is the yellowing and eventual whitening of several of the seedling leaves especially the upper halves. This will give the treated crop an overall yellow and wilted appearance.

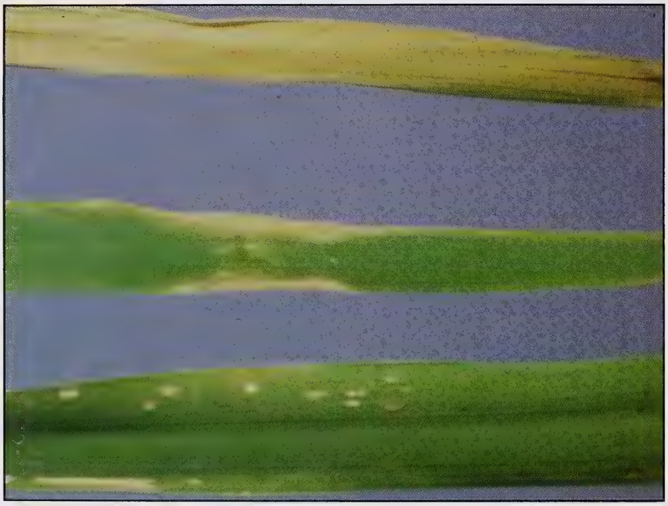

Figure 9

Figure 10

Figure 11.

Crop seedlings recover and are green two weeks after application (lower leaves remain yellow). The initial effect is not thought to reduce yield.

Figure 11

Figure 12

Figure 12:

Severe injury on some crops will eventually lead to root and shoot growth inhibition and a loss in vigor of the plants.

Parallel Symptoms

Figure 13

Figure 13.

Heat bending in cereals may cause chlorosis and eventual whitening of some leaves on a plant.

III. BENZOICS

Dicamba

General uses

Control of a number of broadleaved weeds in barley, wheat, oats, corn, and forage grasses; weeds and brush in pasture and rangeland grasses, and noncrop areas.

Symptoms in plants

Injury symptoms typical of growth-hormone herbicides — bending of young stems and petioles, cupping and curling of leaves followed by necrosis of those leaves, defoliation, swelling of stem and death of the growing points.

Behavior and fate in plants

Readily absorbed by leaves and roots and translocated in phloem and xylem. Accumulates in young tissues and interferes with growth. Plant death occurs from extensive growth abnormalities. Readily degraded in plants, especially in tolerant species.

Behavior and fate in soil

Relatively mobile in the soil. Generally, the concentration and location in the soil profile determined by the total seasonal precipitation, its frequency, and the original herbicide dosage. Readily broken down by soil organisms. Half life is two to three weeks in warm moist soils.

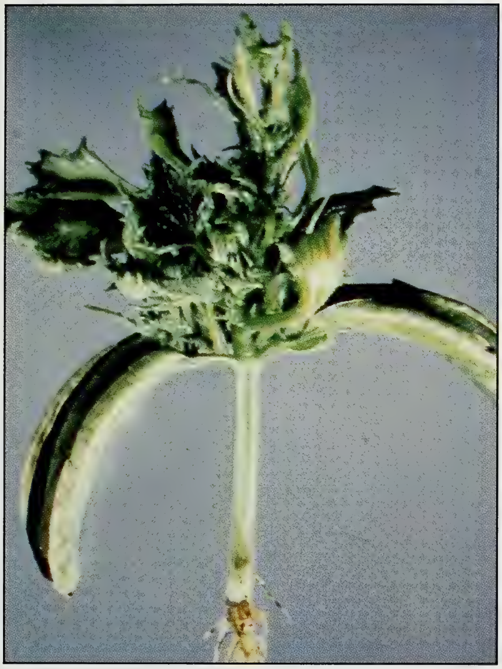

Figure 14

Figure 15

Figure 16

Effect on Weeds

Figures 14, 15 and 16.

Like other hormonal herbicides, dicamba causes a proliferation of tissue, twisting and bending of the main stem and leaf petioles, and in some cases stimulates adventitious root production.

Dicamba

Figure 17

Figure 18

Figures 17 and 18.

Dicamba acts slowly; deformed weeds may remain green but not actively growing for up to 3 weeks after application.

Crop Injury

Figure 19

Figure 20

Figure 19.

Excessive rates or too early an application of dicamba will cause barley stems to grow almost flat on the ground. As the plant matures the culms will have abnormally sharp bends at the internodes. The plant will display less than erect growth for the rest of the season as a result of this injury.

Figure 20.

Severely kinked heads and curled awns, and in some cases sterile florets may result from late application of dicamba.

Dicamba

Figure 21.

Fiddleheading and an inward curling of leaves on potato and other closely related crops can result from dicamba drift, residues in soil or in tubers.

Figure 21

Figures 22 and 23.

Leaf and petiole curling is replaced by leaf yellowing and browning when soil residues of dicamba influence deciduous trees and shrubs. This type of injury has been caused by the careless use of a lawn herbicide or herbicide-fertilizer mixtures over the root zone of ornamental shrubs.

Figure 22

Figure 23

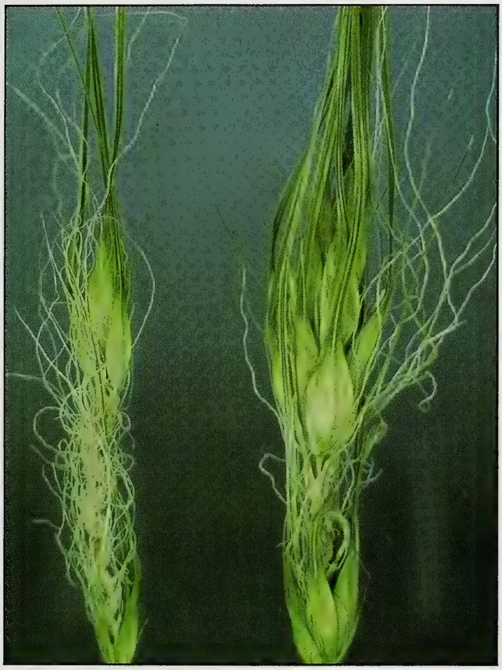

Figure 24

Figure 25

Parallel Symptoms

Figure 24.

Deformed awns and missing florets can be produced by untimely frosts. A light frost when the Olli barley was in the boot stage resulted in symptoms similar to dicamba injury.

Figure 25.

Barley thrips may produce similar effects.

Figure 26.

Cupping of leaves caused by eriophyid mites on elder may resemble injury symptoms produced by dicamba and other growth-hormone herbicides.

Figure 26

Dicamba

Figure 27

Figure 28

Figure 29

Figure 27.

Aphid damage on poplar can sometimes be confused with injury symptoms produced by dicamba and other growth-hormone herbicides

Figure 28.

Rust damage on Canada thistle may resemble leaf malformations caused by sublethal doses of dicamba.

Figure 29.

Inward leaf curling is normal in a vigorously growing tomato plant. General appearance is similar to dicamba injury.

IV. BIPYRIDILIUMS

Diquat, Paraquat

General uses

Used as a general contact foliage-applied herbicide on noncrop land. Diquat also used as an aquatic herbicide and as a preharvest top killer or desiccant of seed crops.

Symptoms in plants

Cause rapid desiccation of treated leaves. Wilting, an early symptom of this desiccation, is followed by necrosis and ultimately death of the entire leaf.

Behavior and fate in plants

Rapidly absorbed by leaves of most species. Most of the chemical from leaf surfaces absorbed within 24 hours. Not translocated from treated leaves. Cause death of leaf cells. Very resistant to removal by rain. Photochemical degradation occurs on plant surfaces.

Behavior and fate in soil

Rapidly and completely inactivated in soil through tenacious binding with soil particles. Most soils have sufficient capacity in the top 2-3 cm alone to bind many hundred times the normal field rates of application of these herbicides. Soil-bound diquat or paraquat not degraded by microorganisms.

Diquat Paraquat

Effect on Weeds

Figures 30, 31 and 32.

Owing to rapid action, wilting and interveinal discoloration will appear within hours of paraquat or diquat application. This is followed in some species by leaf-edge blackening followed by complete browning of the top growth.

Figure 30

Figure 31

Figure 32

Figure 33

Figures 33 and 34.

Since diquat and paraquat control top growth only, regrowth occurs in woody and herbaceous species.

Figure 34

Diquat Paraquat

Crop Injury

Figure 35

Figure 36

Figure 35.

Accidental drift onto cereal crops in the spring results initially in some leaf death and often some delay in crop maturity.

Figure 36.

Drift onto woody plants will result in leaf browning and therefore in loss of aesthetic value for one year. None of the symptoms will be present on the trees the following spring.

Figure 37

Figure 38

Figures 37 and 38.

Light drift from a dessicant application can produce brown spotting on garden plants such as cabbage and gladiolus. If spotting is extensive, affected leaves should be removed before storage or use.

Figure 39

Figure 39.

Severe drift injury will result in wilting of plants. The dried leaves may be curled and cupped.

Parallel Symptoms

Figure 40

Figure 41

Figure 40.

Some stages of bacterial speck of tomatoes resemble diquat or paraquat drift injury.

Figure 41.

Pear slugs on cotoneaster cause spotted necrotic injury which may resemble contact injury from bipyridilum herbicides.

V. CARBAMATES

Barban, Asulam

General uses

Barban selectively controls wild oats at the one to two leaf stage in wheat, barley, flax, canola, peas, sugarbeets, alfalfa, clovers, lentils and several forage grasses. Asulam is used in postemergence application to control wild oats at the two to four leaf stage in flax and alfalfa.

Symptoms in plants

Inhibit shoot growth resulting in general stunting. Barban-treated wild oat plants show dark bluish coloration. Injured cereal crops may show yellowing of the emerging leaves. Asulam-treated wild oat plants show gradual yellowing of the new growth.

Behavior and fate in plants

Readily absorbed through leaf surfaces and leaf axils. Translocation of barban limited to short distances from the site of entry. Asulam translocation is much more extensive and occurs in xylem and phloem. These herbicides inhibit growth. They are degraded quite rapidly in most plant species.

Behavior and fate in soil

Fairly rapidly degraded in soils by microorganisms. Under most soil conditions disappear in three or four weeks.

Barban

Effect on Wild Oats

Figure 42

Figure 43

Figures 42 and 43.

Within 5-10 days of barban application the wild oats are stunted and have turned a dark bluish green. At the same time a slight swelling, because of abnormal development of the seedling, appears in the crown area.

Figure 44

Figure 45

Figures 44 and 45.

Although wild oat plants may not be dead four to six weeks after barban application, the stunted unthrifty plants do not offer much competition to crops.

Barban

Crop Injury

Figures 46 and 47.

Occasional reports of barban injury to cereals have been received, however, in the laboratory triple the recommended rate was required to simulate injury. These rates inhibited the extension of the second and subsequent leaves in barley, resulting in distorted growth. In canola, some leaf crinkling and spots of dead tissue were produced. Under field conditions, low temperatures immediately after barban application appear to cause this injury.

Figure 46

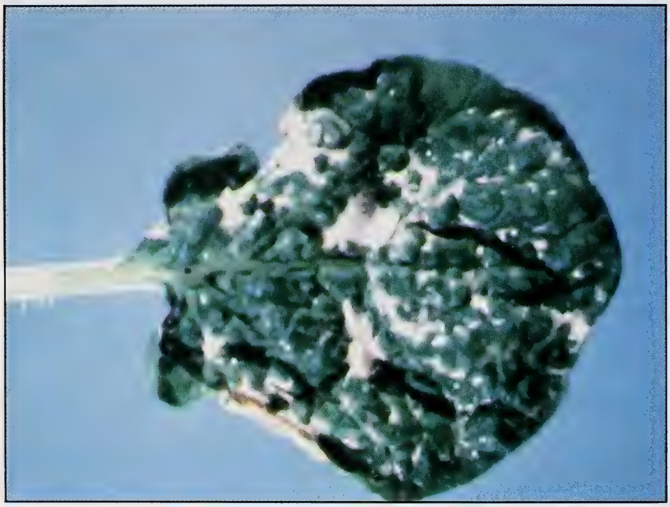

Figure 47

Parallel Symptoms

Figure 48.

The appearance of seedling blight on barley occasionally coincides with the application of barban and may be mistaken for barban injury.

Figure 48

Figure 49

Figure 51

Effect on Wild Oats

Figures 49 and 50.

Wild oats affected by asulam show severe yellowing of new leaves. This is followed by plant stunting and death of wild oats three to four weeks after application. Affected wild oat plants are on the right.

Figure 50

Crop Injury

Figure 51.

Under adverse conditions asulam has caused yellowing and death of the main shoot of flax. In these instances the axillary buds are stimulated, resulting in good yields but somewhat delayed maturity.

VI. DINITROANILINES

Trifluralin

General uses

A soil-applied herbicide to control certain annual grassy and broadleaved weeds such as green foxtail, wild oats, barnyard grass, Persian darnel, chickweed, wild buckwheat, pigweed and lamb's quarters in wheat, barley, canola, peas, sunflowers, soybeans, lentils, flax, beans, carrots, turnips, cauliflower and cabbage.

Symptoms in plants

Inhibits root and shoot growth. Initial effect is on root growth, especially the development of the lateral or secondary roots. Causes thickened and stubby roots. Inhibition of shoot growth following root absorption is a secondary effect caused by limited root growth.

Behavior and fate in plants

Readily absorbed by roots and shoots but little or no apparent translocation. Interferes with growth. Degraded slowly by most plants. Roots of plants grown in soil containing trifluralin may contain some residues, but only in the region of contact with the herbicide.

Behavior and fate in soil

Can be lost from wet soil surfaces by volatilization and breakdown in sunlight if not incorporated immediately after application. Strongly adsorbed on soil particles, therefore leaching is negligible. Microorganisms contribute greatly to degradation and disappearance from soil. At recommended rates under normal growing conditions 10-25 per cent may remain in soil after one year.

Effect on Weeds

Figures 52 and 53.

Swelling in the coleoptile region, stubby, thick primary root development and lack of any significant secondary root development are typical effects of trifluralin on susceptible broadleaved and grassy species. Most weeds affected by trifluralin do not emerge, but if they emerge, the development of one or two leaves is common.

Figure 52

Figure 53

Crop Injury

Figures 54 and 55.

Excessive amounts of trifluralin residues in soil, for example from herbicide spill, can cause injury to emerging seedlings of grassy crops such as wheat, barley and corn. Root and shoot development may be severely affected.

Figure 55

Figure 54

Trifluralin

Figures 56, 57 and 58.

In many cases surviving seedlings may continue to grow into healthy-looking plants but lack normal secondary root development. In affected juvenile and mature plants, root, tiller and head development are usually poor.

Figure 56

Figure 57

Figure 58

Figure 59

Parallel Symptoms

Figure 59.

Alfalfa stem nematodes cause swollen stems on seedlings similar to trifluralin injury.

VII. DIPHENYL ETHERS

Diclofop methyl

General uses

A foliar-applied selective herbicide for the control of annual grassy weeds such as barnyard grass, green foxtail, Persian darnel and wild oats. Some of the tolerant crops include rye, barley, wheat, flax, canola, peas, lentils, beans, potatoes, and alfalfa.

Symptoms in plants

Exhibits contact-type injury symptoms as well as general growth inhibition in sensitive plants. The first visual symptom is chlorosis of old and new leaves. The chlorosis, characterized by yellowing, gradually expands to cover the entire plant. Shoot and root growth are also inhibited. Susceptible plants wilt in about two to three weeks.

Behavior and fate in plants

Absorbed by leaves and roots. Limited translocation in xylem and phloem. Inhibits photosynthesis and root and shoot growth. Initially converted to a toxic chemical (diclofop acid) in susceptible and tolerant plant species. In tolerant species diclofop acid is rapidly degraded to nontoxic compounds, while in susceptible species detoxification is limited.

Behavior and fate in soil

Slow and limited downward or lateral movement in soil. Degraded by microorganisms. Half life of diclofop methyl is 10-25 days.

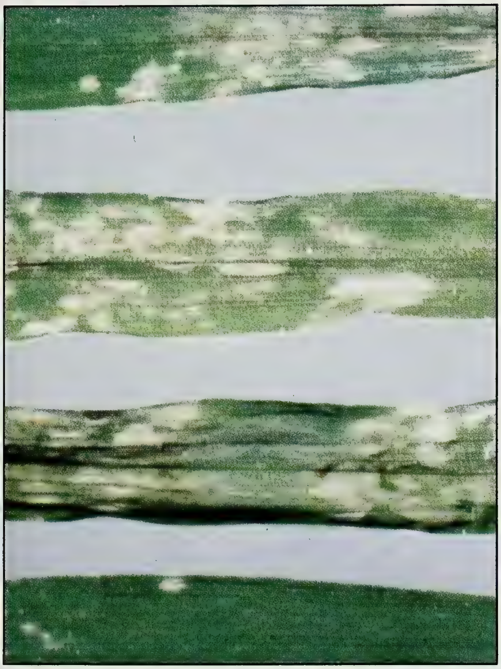

Figure 61

Effect on Weeds

Figures 60 and 61.

Yellowing of susceptible plants becomes noticeable within two to four days of application.

Figure 60

Figure 62

Figures 62 and 63.

Yellowing deepens and browning develops within 10-14 days of application.

Figure 63

Diclofop methyl

Figure 64

Figure 65

Figure 66

Figures 64 and 65.

While an early application will result in excellent control of Persian darnel, a late application causes seedhead bolting. A similar effect can be expected on wild oats.

Figure 66.

Lack of adequate crown root development is one of the most distinguishing features of diclofop activity.

Crop Injury

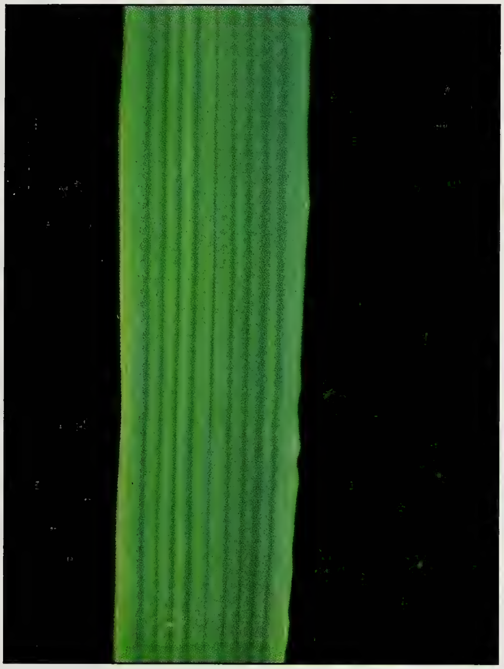

Figure 67

Figure 68

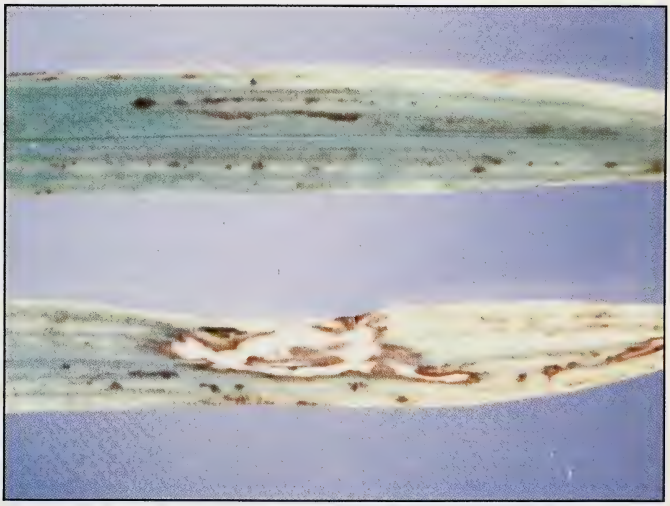

Figure 69

Figure 70

Figures 67, 68, 69 and 70.

Interveinal leaf yellowing is one of the first noticeable effects on barley when diclofop is applied at improper rates or times, or to the wrong variety. This is followed by leaf browning and stunting, and inhibition of crown root development. Stems may get weaker at the base and break off.

Diclofop methyl

Parallel Symptoms

Figure 71.

Yellowing and browning of leaf in barley caused by net blotch may resemble diclofop methyl injury.

Figure 71

VIII. NITRILES

Bromoxynil

General Uses

A postemergence herbicide mainly used to control annual broadleaved weeds in wheat, barley, oats, rye, corn and seedling grasses.

Symptoms in plants

Basically a foliar contact herbicide. Causes blistered or necrotic spots within 24 hours and extensive destruction of leaf tissue later. Chlorosis may appear afterwards around the necrotic areas of the leaf.

Behavior and fate in plants

Absorption of bromoxynil by leaves is rapid but varies with species. Translocation in plants is extremely limited. Inhibits photosynthesis and respiration. Degraded slowly to nontoxic compounds.

Behavior and fate in soil

Downward movement with water through the soil is extremely slow. Degraded rapidly in soil by microorganisms. Does not persist into the following crop year.

Effect on Weeds

Figures 72, 73 and 74.

A general discoloration and mottling appear on bromoxynil-susceptible plants one to two days after application. Mottling is intensified and plants brown completely and shrivel within four to seven days of application.

Figure 72

Bromoxynil

Figure 73

Figure 74

Figure 75.

Susceptible seedlings become extremely brittle and eventually disintegrate. More mature weeds, while appearing to be controlled, may eventually recover and continue normal growth and development.

Figure 75

Crop Injury

Figure 77

Figure 78

Figure 76

Figure 76.

Although bromoxynil and its combinations are about the safest herbicides on cereals and flax, some general wilting and leaf tip browning has been known to occur when bromoxynil was applied under high humidity conditions or when soils were cold and dry.

Figures 77, 78 and 79.

Spray drift of bromoxynil on broadleaved crops such as fababeans, peas and canola results in severe contact injury on leaves. The surviving plants may continue to grow and flower but the leaf area is drastically reduced.

Bromoxynil

Figure 79

Parallel Symptoms

Figure 80.

Low moisture conditions can produce an effect similar to the bromoxynil high-humidity combination (back flat).

Figure 80

IX. PHENOXYS

2,4-D, MCPA & Others

Figure 81

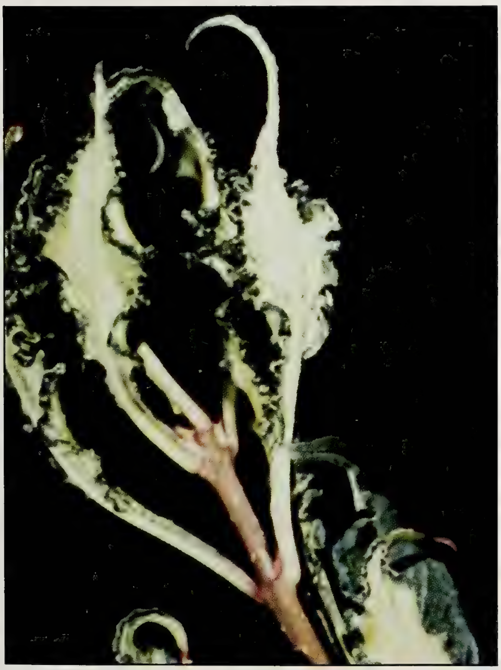

Figure 82

General uses

Commonly-used herbicides in this group include 2,4-D, MCPA, 2,4-DB, MCPB, dichlorprop and mecoprop. Effective against broadleaved weeds in cereal crops, turf, pasture and noncrop land. Alfalfa, clover, peas and beans are tolerant to 2,4-DB and MCPB, but not all legumes are.

Symptoms in plants

Induce abnormal growth typical of growth-hormone herbicide injury symptoms, resulting in stem or petiole bending, leaf curling and cupping, and in development of abnormal tissues and secondary roots.

Behavior and fate in plants

Absorbed readily by leaves and roots. Translocated in phloem and xylem. Accumulated in the growing points of shoots and roots. Interfere with growth. Plant death occurs from growth abnormalities. Readily degraded to nontoxic compounds.

Behaviour and fate in soil

Undergo rapid microbial breakdown in warm moist soil. Minor loss may occur through breakdown by sunlight. Average persistence in soil under favorable conditions is generally two to four weeks.

Effect on Weeds

Figures 81 and 82.

Unequal rates of elongation in the stem, petiole and the leaf margins cause bending, twisting and leaf cupping. Phenoxy esters can produce these symptoms within hours of application on highly susceptible plants.

2,4-D, MCPA & Others

Figure 83.

Excessive adventitious root development in the primary root as well as in the leaf axils of susceptible plants are characteristic of mixtures containing MCPA and mecoprop.

Figure 83

Figure 84

Figure 85

Figures 84 and 85.

Gall-like growths are generally produced when plants are exposed to sublethal doses of phenoxy herbicides.

Figure 86

Crop Injury

Figure 87

Figures 86 and 87.

Early or late application of 2,4-D or at greater than recommended rates may result in bent spikes, shorter heads, missing florets, and reduced yields of wheat.

2,4-D, MCPA & Others

Figures 88, 89, 90 and 91.

Phenoxy drift onto seedling and rosette stages of canola will result in leaf curling, leaf yellowing, and eventual plant death. Exposure during flowering results in upper stem bending, loss of existing flowers, abortion of pods, and a reduction in seed numbers in retained pods.

Figure 88

Figure 89

Figure 90

Figure 91

Figure 92

Figure 93

Figures 92 and 93.

A light spray drift from phenoxys, alone or in mixtures with other herbicides, onto broadleaved and coniferous trees will cause leaf curling and cupping, and needle and stem twisting.

2,4-D, MCPA & Others

Figure 94

Figure 95

Figures 94, 95 and 96.

Fusion during ovary formation can result in abnormal tissue formation (tomato) or multiple-fruit set (pepper).

Figure 96

Figure 97

Figure 98

Figures 97 and 98.

Sublethal doses of phenoxy herbicides in some root crops produce the characteristic hourglass shape shown by the red beet and turnip.

Parallel Symptoms

Figures 99, 100, and 101.

Early stages of the fungal disease staghead, which affects Polish canola and some other cruciferous plants, including weeds, produce symptoms strikingly similar to those resulting from phenoxy drift. Staghead infections do not have the characteristic field patterns resulting from herbicide drift.

Figure 99

Figure 101

Figure 100

Figure 102

Figure 103

Figures 102 and 103.

Fireblight on raspberry and fusarium wilt on aster can result in leaf curling and cupping and stem bending which may be confused with phenoxy herbicide drift injury.

2,4-D, MCPA & Others

Figures 104 and 105.

Sometimes thrips can cause severe damage to leaves and fruits that resemble phenoxy herbicide drift injury.

Figures 106 and 107.

Sometimes damage caused by green fruit worm and spruce budworm to foliage of broadleaved and coniferous trees may be confused with injury symptoms caused by phenoxy drift.

Figure 104

Figure 105

Figure 106

Figure 107

Figure 108

Figure 108.

Heat canker in carrots results in a deformity similar to that caused by sublethal doses of phenoxy herbicides.

Figure 109

Figure 109.

Copper deficiency in soil can cause awn deformities and poor head development in barley that may be confused with injury caused by phenoxys when applied at the wrong growth stage and/or at higher than the recommended rates.

X. PYRIDINECARBOXYLIC ACIDS

Clopyralid, Picloram

General uses

Selective control of annual and perennial broadleaved weeds in crops such as wheat, barley, oats, corn, and canola, and brush control in range lands and along rights-of-way.

Symptoms in plants

Cause growth-hormone injury symptoms: stem and petiole bending and swelling, cupping and curling of leaves and general growth stunting. At low concentrations tips of new leaves may develop into narrow extensions of the midrib (feathering of leaves).

Behavior and fate in plants

Readily absorbed by leaves and roots and translocated throughout the plant. Accumulate mainly in the growing points and interfere with growth. Plants die as a result of extensive abnormal growth. Slowly degraded by plants; straw of cereal crops may contain active residues.

Behavior and fate in soil

Not strongly adsorbed on soil particles; leaching occurs in sandy soils low in organic matter. Some loss may occur through breakdown by sunlight. Degradation by soil microbes occurs slowly, but is the major source of their dissipation. Because clopyralid is less persistent than picloram most broadleaved crops can be grown the year after its application at recommendated rates. Picloram may persist for two to five years depending on the rate of application and soil and climatic conditions. In western Canada up to 40 per cent of the applied picloram may remain after one year.


Figure 111

Effect on Weeds


Figure 110

Figures 110, 111, 112 and 113.

Causes leaf curling and cupping within a day or two of application. At sublethal dosage plants may not die but exhibit severe leaf malformations. At lethal dosage susceptible annual and perennial weeds usually turn brown and die in two to four weeks.

Clopyralid

Figure 112

Figure 113

Crop Injury

Figure 114

Figure 115

Figures 114, 115, 116, 117 and 118.

Crops in the grass and the mustard families are tolerant to clopyralid, but those in the pulse and the sunflower families are quite susceptible. Alfalfa, fababeans, peas and sunflowers may be injured with clopyralid drift and show defects such as stem bending, leaf curling and cupping, yellowing of the young growing point and browning of leaves.

Clopyralid

Crop Injury

Figure 116

Figure 117

Figure 118

Effect on Weeds

Figure 119

Figure 120

Figure 121

Figures 119, 120 and 121.

The initial effect of picloram is a loss of turgidity followed by a severe distortion of stems and leaf petioles. Mature persistent perennial weeds and woody plants generally remain semi-erect until death.

Picloram

Crop Injury

Figure 123

Figure 124

Figures 122, 123, 124 and 125.

Picloram drift or traces left in the soil are known to induce fiddleheading in potatoes, beans, peas and other highly susceptible species. Higher concentrations stop terminal growth.

Figure 122

Figure 125

Figure 126

Figure 127

Figure 128

Figures 126 and 127.

At rates sufficiently high to control persistent perennials such as field bindweed, the residue seriously reduces cereal growth for several years after application. Twisted awns, deformed heads, and prostrate growth are typical symptoms on surviving plants.

Figure 128.

Crinkled and chlorotic leaf edges may be produced by sublethal soil residues on moderately tolerant species.

Picloram

Figures 129 and 130.

Severe drift or accidental application of picloram onto coniferous trees will cause drooping of new growth and light yellowing in the beginning but eventually may lead to plant death.

Figure 129

Figure 130

Figure 131

Figure 132

Parallel Symptoms

Figures 131 and 132.

Rhizoctonia solani infections on potato tubers (Fig. 131) resemble symptoms on tubers grown in soils containing trace levels of picloram (Fig. 132).

Figure 133

Figure 134

Figures 133 and 134.

Viral infections of fababeans and ornamental plants cause leaf distortions similar to those produced by picloram.

Figure 135.

Thrips damage to poplar leaves can cause feathering of leaves similar to that caused by picloram.

Figure 135

XI. SULFONYLUREAS

Chlorsulfuron, Metsulfuron methyl

General uses

A relatively new class of herbicides. Both compounds are effective at extremely low rates of application. Control annual and perennial broadleaved weeds in cereal crops. May also be used to control brush species.

Symptoms in plants

Stop shoot and root growth in sensitive species. A few days after application chlorosis, necrosis, terminal bud death, and vein discoloration and decline in plant vigor are frequently observed. Yellow and purple coloration appears on leaves and stems of canola and mustard. In other species, such as fababeans, browning and black coloration of leaves occur. Inhibition of secondary root development in sensitive plants occurs from soil residues.

Behavior and fate in plants

Readily absorbed by leaves and roots and translocated throughout the plant. Accumulate in growing points and inhibit cell division, photosynthesis and respiration. Broken down to nontoxic compounds.

Behavior and fate in soil

Adsorption on soil particles is low. Rate of leaching is correlated with net movement of soil moisture and with soil pH. Volatilization and breakdown by sunlight play minor roles in disappearance. Degraded by soil microbes. The half life of chlorsulfuron is six to eight weeks under most western Canadian conditions. Trace level residues can cause injury the following years to alfalfa, lentils, sugarbeets and other sensitive crops. Metsulfuron methyl is considered less persistent.

Effect on Weeds

Figures 136, 137, 138, 139 and 140.

These herbicides cause yellowing and browning of the young leaves, especially at the margins, within a week of application. Plants usually stop growing. Later on yellowing and browning develop on the entire leaf, and vein discoloration and terminal bud death occur.

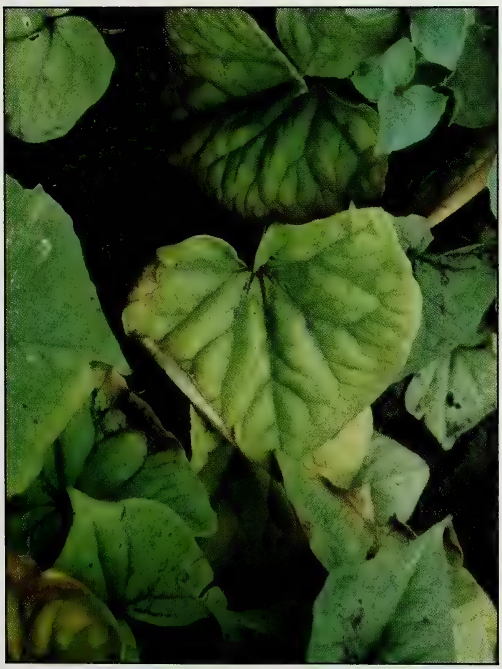

Figure 136

Figure 137

Figure 138

Figure 139

Figure 140

Figure 141

Figure 142

Figures 141 and 142.

At lethal dosage susceptible plants turn brown and die in approximately three weeks. At sublethal dosage plants may not die completely but remain stunted and weak.

Chlorsulfuron, Metsulfuron methyl

Crop Injury

Figure 143

Figure 144

Figure 145

Figures 143, 144, 145, 146 and 147.

Most broadleaved crops are quite sensitive to drift or accidental foliar sprays of these herbicides. For example as low as 1 g/ha can cause severe injury to canola. Typical injury symptoms of drift on canola include general growth retardation, yellowing, purpling and browning of leaves, and terminal bud death. The affected plants that survive usually produce several branches on the stem below the terminal bud.

Figure 146

Figure 147

Figure 148

Figure 149

Figures 148 and 149.

Pod formation and development in canola plants affected by drift is greatly inhibited. The pods tend to develop in clusters on the stem.

Chlorsulfuron, Metsulfuron methyl

Figures 150, 151, 152, 153 and 154.

Other sensitive crops such as corn, fababeans, lentils and peas show blackening, browning and/or yellowing of the foliage as a result of drift damage from sulfonylurea herbicides.

Figure 150

Figure 151

Figure 152

Figure 153

Figure 154

Chlorsulfuron, Metsulfuron methyl

Figures 155, 156, 157 and 158.

Crops vary greatly in their sensitivity to soil residues of these herbicides. Shoot and root growth of sensitive crops such as alfalfa, corn and lentils can be severely affected if planted in soil containing herbicide residues. A purple coloration may develop on leaves of the affected plants. In established sainfoin, soil residues of chlorsulfuron may produce some yellowing of new growth without causing serious damage to the plant.

Figure 156

Figure 155

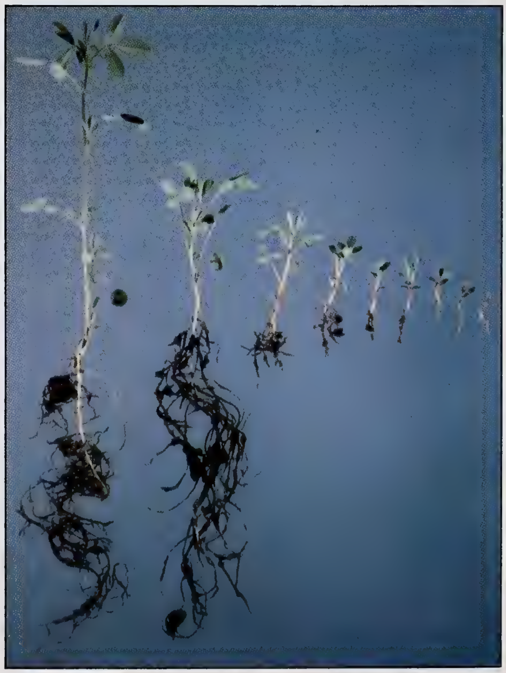

Figure 157

Figure 158

Figure 159

Figure 159.

In potatoes soil residues of these herbicides may not cause shoot damage but tuber formation and development are greatly inhibited.

Chlorsulfuron, Metsulfuron methyl

Parallel Symptoms

Figure 160

Figure 161

Figure 160.

Aster yellows virus in lettuce may cause yellowing of new leaves and general growth retardation that may resemble damage caused by soil residues of these herbicides.

Figures 161 and 162.

In canola, sulfur deficiency produces purple coloration on leaves, stem and pods, and result in poor bud development that may be confused with chlorsulfuron damage.

Figure 162

Figure 163

Figure 163.

Aster yellows disease on canola produces symptoms that may resemble chlorsulfuron injury.

XII. THIOCARBAMATES

Triallate

General use

A soil-applied herbicide for the control of wild oats during seed germination or early seedling growth in wheat, barley, flax, canola, peas, mustard, alfalfa and clovers. EPTC, another commonly-used herbicide of this group, is used for control of annual grassy and many broadleaved weeds in several crops.

Symptoms in Plants

Inhibits the growth of shoots of germinating seedlings to a greater degree than the roots. Induces abnormal growth and emergence of the leaves from the coleoptiles of grasses. Kinking of the first internode into a zigzag pattern often appears. At high rates leaves may not emerge but remain longitudinally rolled or emerge through the base of the coleoptile. Such a leaf may elongate to form a loop with its tip fixed within the coleoptile tip. The leaves of affected plants often appear darker green than those of unaffected plants. In broadleaved plants the injury symptoms are less specific; growth may be generally inhibited and the leaves may be cupped with necrotic tissue around the edges.

Behavior and fate in plants

Absorbed more readily by the emerging seedling shoots than by the roots. Readily translocated from root to shoot in the xylem. Inhibits cell division and cell elongation in the growing point of the shoot. Degraded slowly in plants.

Behavior and fate in soil

Readily lost by volatilization from wet soil surfaces if not incorporated immediately after application. Adsorbed on soil particles in dry soil. Microbial degradation mainly responsible for disappearance from soil. Under normal conditions the half life of triallate is about three weeks.

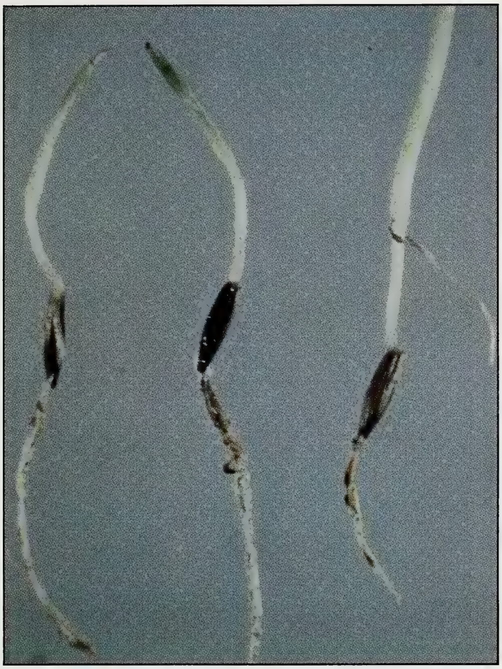

Figure 164

Effect on Wild Oats

Figure 165

Figure 166

Figures 164 and 165.

Since triallate is absorbed by the wild oat plant in the vicinity of the emerging shoot, most affected wild oat seedlings do not emerge. Numerous chlorotic and bleached shoots may be visible by removing the top few inches of treated soil.

Figure 166.

In some instances triallate allows limited emergence of the first wild oat leaf but it will be distorted, brittle, dark green, and glossy.

Triallate

Crop Injury

Figure 167.

Triallate is not registered for use on oats because the action is similar to that produced on wild oats.

Figure 167

Figure 168

Figure 169

Figures 168 and 169.

Triallate injury to wheat results in an elongation of the area between the seed and the crown, production of distorted tillers at the seed node and the crown, excessive tillering, and a delay in growth.

Figure 170

Figure 170.

Injury in fields can be spotty, with shallow or excessively deep-seeded areas most likely affected.

Parallel Symptoms

Figure 171

Figure 171.

Propane leaks from a buried line may cause crop stunting or severe thinning which can resemble triallate injury.

XIII. TRIAZINES

Atrazine, Cyanazine, Metribuzin, Simazine

General uses

Foliar- and soil-applied for selective and nonselective weed control. Atrazine for weed control in corn and general vegetation control; cyanazine and metribuzin for weed control in cereal crops and triazine-tolerant canola; and simazine for total vegetation control on noncrop lands.

Symptoms in plants

The usual injury symptoms include chlorosis followed by necrosis and wilting. Symptoms are more pronounced at the leaf tips and margins. Older leaves generally are the worst affected. Sublethal concentrations can cause increased greening of leaves in some species.

Behavior and fate in plants

Absorbed by leaves and roots. Translocated in the xylem only. Accumulated in leaves. Inhibit photosynthesis. In tolerant species degraded rapidly, while in susceptible species degraded slowly.

Behavior and fate in soil

Reversibly adsorbed on soil particles. Degree of adsorption varies with soil texture, organic matter, water content and pH. Leaching is limited because of adsorption on soil particles. Microbial breakdown mainly responsible for their disappearance in soil. Rate of disappearance varies with each herbicide. Cyanazine and metribuzin persist for short periods with half lives of about three weeks. Atrazine and simazine persist longer and even under favorable conditions 10 per cent or more may remain in soil after one year.

Figure 172

Effect on Weeds

Figures 172, 173 and 174.

Triazines interfere with plant photosynthesis resulting in wilting, leaf yellowing and eventual browning, beginning with the tip and margin of the older leaves and proceeding towards the base of the plant.

Figure 174

Figure 173

Atrazine, Cyanazine, Simazine

Crop Injury

Figures 175 and 176.

Generally, the symptoms of crop injury resulting from triazine exposure are the same as those present on affected weeds. With plants such as radish, sublethal rates may result in an increased chlorophyll content of leaves and therefore a temporary darker green coloration.

Figure 175

Figure 176

Figure 177.

In triazine-tolerant canola, postemergence application of cyanazine may result in temporary yellowing of older leaves. Although the affected leaves may be lost, the plants usually recover and grow normally.

Figure 177

Effect on Weeds

Figure 178

Figure 179

Figures 178 and 179.

Within several days of application, leaf margin discoloration develops, particularly on the older leaves. Discoloration continues towards the base, followed by crisping and complete browning. Control of susceptible species occurs within two weeks.

Figure 180

Figure 180.

Sprayed perennials such as Canada thistle will also exhibit some chlorosis and browning of the leaves. Affected plants will remain stunted.

Metribuzin

Crop Injury

Figure 182

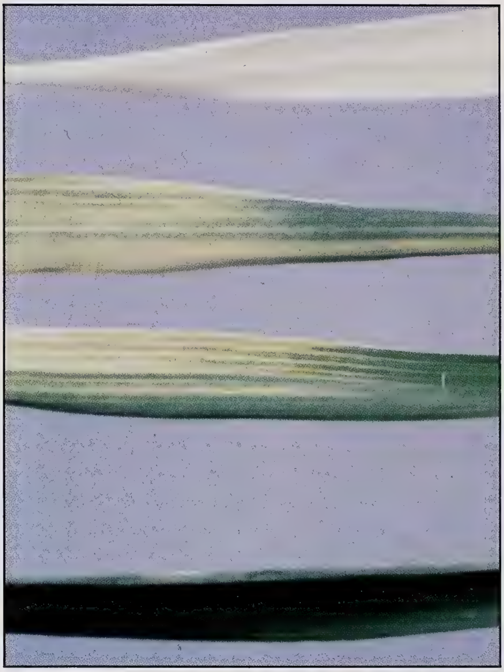

Figure 181

Figures 181, 182, 183 and 184.

After metribuzin application, leaf yellowing interveinally and at the leaf margins may be aggravated by environmental stress such as low temperature. Yellowing caused by such conditions disappears a few days after cessation of the stress. The whitened leaves, although not visible after one to two weeks, are effectively lost to the plant.

Figure 183

Figure 184

Figure 186

Parallel Symptoms

Figures 185 and 186.

Lime-induced chlorisis may resemble metribuzin injury, but it can be differentiated in most cases by its occurrence in the interveinal areas only.

Figure 185

Figure 187

Figure 187.

Severe magnesium deficiency symptoms that sometimes appear on cucumbers in a greenhouse may be confused with triazine herbicide injury.

Metribuzin

Figure 188

Figure 189

Figures 188 and 189.

Leaf yellowing resulting from eriophyid mite damage on golden plume elder, and from bean yellow mosaic virus damage on peas can resemble yellowing caused by triazines.

XIV. TRIAZOLES

Amitrole

General uses

A foliar spray for control of grassy and broadleaved weeds in noncropped areas. In mixtures with persistent herbicides used for long-term general vegetation control.

Symptoms in plants

Causes wilting of leaves in two to three days. The most striking symptom is the development of albino leaves and shoots. The whitening may be temporary if the dosage is sublethal, or permanent, resulting in plant death if the dosage is high enough.

Behavior and fate in plants

Readily absorbed by leaves and roots and translocated throughout the plant. Interferes with the development of chloroplasts. Causes chlorophyll destruction and inhibits chlorophyll synthesis in tissues formed at the time or after the absorption of the chemical. Degraded slowly in plants.

Behavior and fate in soil

Disappears rapidly from soil through microbial and non-biological processes. Average persistence at recommended rates in moist, warm soils is approximately two to four weeks.

Amitrole

Effect on Weeds

Figures 190 and 191.

Amitrole application usually results in wilting within one or two days followed by tissue death, starting at the leaf edge and moving towards the base.

Figure 190

Figure 191

Figure 194

Figure 192

Figure 193

Figures 192 and 193.

In amitrole-treated perennial weeds the new growth generally turns white before such plants wilt and die.

Figure 194.

Top growth can be controlled even in species resistant to amitrole but regrowth will occur. The regrowth often appears pinkish-white. As the chemical degrades in the soil and in the plant, the affected parts will eventually produce normal green foliage.

Amitrole

Crop Injury

Figure 195

Figure 196

Figures 195, 196, 197 and 198.

Foliar and root absorption of amitrole produce an initial whitening of foliage, specially the new growth.

Figure 197

Figure 198

Parallel Symptoms

Figure 199

Figure 199.

Whitish-silvery leaves can be induced by the silverleaf disease which can attack many woody species.

XV. URACILS

Bromacil, Terbacil

General uses

Bromacil, a non-selective herbicide, is used on noncrop land for control of a wide range of annual and perennial grassy and broadleaved weeds. Terbacil is used for selective control of many annual weeds in alfalfa and fruit orchards.

Symptoms in plants

Cause interveinal or veinal chlorosis and necrosis (usually browning) in leaves of broadleaved plants. Older leaves generally are the worst affected. In grassy species the chlorosis and necrosis (usually white) starts about mid-leaf and then extends to the tip.

Bahavior and fate in plants

Most readily absorbed by the roots and less so by the leaves. Primarily translocated through the xylem. Accumulated in the leaves. Inhibit photosynthesis. Degraded rather slowly in plants.

Behavior and fate in soil

Readily leached from soil. Microbial degradation is the main mode of disappearance. Loss through volatilization and breakdown by sunlight are negligible. Bromacil persists for one or more years when used as a sterilant.

Effect on Weeds and Crops

Figures 200, 201 and 202.

Bromacil- and terbacil-affected broadleaved plants show browning initially on the leaf margins and then in the interveinal areas of the leaf. This is followed by death of the entire plant.

Figure 200

Figure 201

Figure 202

Figure 203

Figure 204

Figures 203 and 204.

Grassy plants affected by uracil herbicides usually show whitening that starts about midleaf and then extends to the tip.

Bromacil, Terbacil

Figure 205.

Bromacil absorbed by conifers will result in needle yellowing, browning and drop.

Figure 206

Figure 206.

Bromacil persists in the soil for several years and leaves the treated area devoid of any vegetation.

Figure 205

Figure 207

Parallel Symptoms

Figures 207 and 208.

Fireblight on Saskatoon and hawthorn may cause browning of leaves that may resemble uracil herbicide damage. However, unlike herbicide injury, only few branches may be affected initially.

Figure 208

Figure 209

Figure 209.

Lilac leaf miner may cause browning at the leaf margins but the browning may not extend across the veins.

Bromacil, Terbacil

Figure 210

Figure 211

Figures 210 and 211.

In conifers needle cast (left) and the pitch nodule maker, an insect, may produce needle browning and drop.

XVI. UREAS

Diuron, Linuron, Tebuthiuron

General uses

Most urea herbicides are nonselective. Usually applied to the soil, however, some are active through the leaves. Diuron at high rates is used as a general weed killer in noncropped areas. At low rates used for vegetation control in irrigation and drainage ditches. Linuron selectively controls annual grassy and broadleaved weeds in corn, wheat, barley, carrots, potatoes and soybeans. Tebuthiuron is used for general vegetation control as a soil sterilant.

Symptoms in plants

Symptoms associated with high concentrations of these herbicides in leaves appear within a few days. Initially, veinal chlorosis appears which then takes on a water-soaked appearance. This then becomes necrotic which is usually brown in broadleaved plants and white in grassy plants. Symptoms occurring at relatively low concentrations require several days to develop. These include wilting of the leaves, especially at the tip, the appearance of silver and/or indeterminate gray blotches and rapid yellowing. In some cases veinal chlorisis develops.

Behavior and fate in plants

After soil application, readily absorbed by the roots and rapidly translocated in the xylem to the upper plant parts. After foliar application, translocated in xylem with little, if any, leaving the treated leaves. Accumulate in leaves and inhibit photosynthesis. Readily degraded by tolerant plants.

Behavior and fate in soil

Adsorbed on soil particles and, therefore, not leached readily. Microbial breakdown is the primary source of disappearance in soil. Persistence in soil varies with different urea herbicides, the application rates, soil and climatic conditions. At soil-sterilant rates some of these herbicides will persist for several years.

Effect on Weeds

Figure 212

Figure 213

Figure 214

Figure 215

Figures 212, 213, 214 and 215.

The initial effect of urea herbicides is leaf-tip dieback beginning on the older leaves. This is followed by a water-soaked wilted appearance, progressive yellowing, stem collapse, and eventual browning and plant death.

Figure 216

Figure 216.

Ureas mixed with phenoxys for use in cereals show evidence of both urea and phenoxy activity.

Crop Injury

Figure 217.

Linuron-MCPA injury to cereals consists of chlorisis and tip browning particularly on the older leaves.

Figure 217

Duron, Linuron, Tebuthiuron

Figure 218.

Urea herbicide injury to conifers will cause yellowing, browning and drop of needles.

Figure 219

Figure 218

Figure 220

Figures 219 and 220.

Diuron and tebuthiuron when used at high rates for total vegetation control along fencelines and around gas well sites leave soil residues for several years. Residues may be carried in surface runoff water and injure field crops.

Parallel Symptoms

Figure 221

Figure 221.

Winter injury symptoms resemble urea-herbicide injury in some species.

XVII. MISCELLANEOUS HERBICIDES

1. Difenzoquat

General uses

A foliar-applied herbicide for selective control of wild oats in wheat, barley and rye.

Symptoms in plants

Causes two types of injury symptoms — a contact-type injury on leaves, and a general growth inhibition. Leaf edge yellowing and tip browning develop within a few days of application. In some cases mottled yellowing may also appear. Plants stop growing and remain stunted.

Behavior and fate in plants

Rapidly absorbed by leaves and translocated short distances mainly in the xylem. Inhibits photosynthesis and growth. Slowly degraded by plants.

Behavior and fate in soil

Strongly adsorbed on soil particles, therefore neither leached nor carried appreciably in runoff water. Not significantly broken down by microorganisms, however, readily degraded in sunlight. Rotational crops can be planted the following year without any problem.

Figure 222

Figure 223

Effect on Wild Oats

Figures 222 and 223.

Leaf edge yellowing and tip browning develop within a few days of application. Stem rupture and sheath browning occur two to three weeks after application.

Difenzoquat

Figure 224

Figure 225

Figures 224 and 225.

The affect of difenzoquat is directly related to coverage. With thorough coverage of the seedling complete kill of the wild oats will result. In dense stands, good coverage is difficult and only stunting may result.

Figure 226

Figure 226.

Some contact injury showing leaf yellowing may develop on certain broadleaved weeds from difenzoquat application.

Figure 227

Figure 228

Crop Injury

Figures 227, 228 and 229.

Some mottled yellowing of the crop may be visible about a week after application and will remain for two weeks. Under adverse weather conditions or when rates higher than those recommended are used, the yellowing may persist longer.

Figure 229

Difenzoquat

Figure 230.

Drift onto canola plants will result in spots of yellow and dead tissue.

Figure 230

Parallel Symptoms

Figures 231 and 232.

Flea beetles feeding on canola cotyledons or bean leaves may produce effects similar to those resulting from difenzoquat drift.

Figure 232

Figure 231

Figure 233

Figure 234

General uses

A postemergence herbicide for selective control of wild oats in wheat, alfalfa and a number of forage grasses.

Symptoms in plants

Yellowing and eventual browning of the leaf edges and tips particularly in the newly emerged leaves. The affected wild oat plants either turn brown and die or remain dark green and stunted.

Behavior and fate in plants

Readily absorbed by leaves and transported to other parts of the plant. Inhibits growth by interfering with cell division and cell elongation in stem internodes. Initially converted to a toxic chemical (flamprop acid) which is degraded to nontoxic compounds in tolerant species.

Behavior and fate in soil

Rapidly degraded in soil through microbial action. Average half life under normal soil and climatic conditions is one to two weeks.

Effect on Weeds

Figures 233 and 234.

The first symptoms of activity of flamprop methyl are a yellowing and evenual browning of the leaf edges and tips particularly in the newly emerged leaves.

Flamprop methyl

Figure 235.

Flamprop methyl inhibits cell elongation in wild oats resulting in stunted and dwarfed plants. The affected wild oats either turn brown and die or remain dark green and stunted. Stunted plants may develop seed heads during the growing season. Such plants offer little competition to the wheat crop.

Figure 235

Crop Injury

Figures 236, 237, 238 and 239.

Injury to wheat varieties and plant species for which flamprop methyl is not recommended consists of leaf yellowing and browning commencing at the leaf tip and leaf margin, and progressing towards the base. Effects are generally not sufficiently severe to produce excessive stunting.

Figure 236

Figure 237

Figure 238

Flamprop methyl

Figure 239

Parallel Symptoms

Figure 240.

Similar injury may be produced by a plant bug found in some annual and perennial grass stands.

Figure 240

3. Fluazifop butyl

General uses

A selective postemergence herbicide for control of annual and perennial grassy weeds and volunteer cereals in broadleaved crops.

Symptoms in plants

The first symptom, usually within two to three days of application, is a cessation of growth. Growing tissue in the nodes and buds become necrotic, young leaves turn yellow and then brown. Older leaves show yellowing, light purpling and browning. Affected plants are usually dead in three to four weeks.

Behavior and fate in plants

Readily absorbed by leaves. Rain falling one hour after application results in only a slight loss of activity. Translocated throughout the plant. Inhibits cell division (growth) and photosynthesis. Initially converted to a toxic chemical (fluazifop acid) which is degraded to nontoxic compounds in tolerant species.

Behavior and fate in soil

Has a low mobility in soil and is rapidly degraded through microbial action in about three weeks.

Fluazifop butyl

Effect on Grass Species

Figure 241

Figure 242

Figures 241 and 242.

In grassy species (weeds and crops) the first visible symptoms of fluazifop butyl, usually within two to three days of application, is a cessation of shoot growth. The youngest leaf shows yellowing within a week.

Figure 243

Figures 243, 244, 245 and 246.

The older leaves also develop yellowing, and turn light purple and brown. The affected plants are usually dead in three to four weeks. Affected plants that are not completely dead may show excessive tillering.

Figure 244

Figure 245

Fluazifop butyl

Figure 246

Parallel Symptom

Figure 247.

Barley stripe caused by the fungus *Pyrenophora* causes yellowing and browning of foliage that may be confused with fluazifop butyl injury.

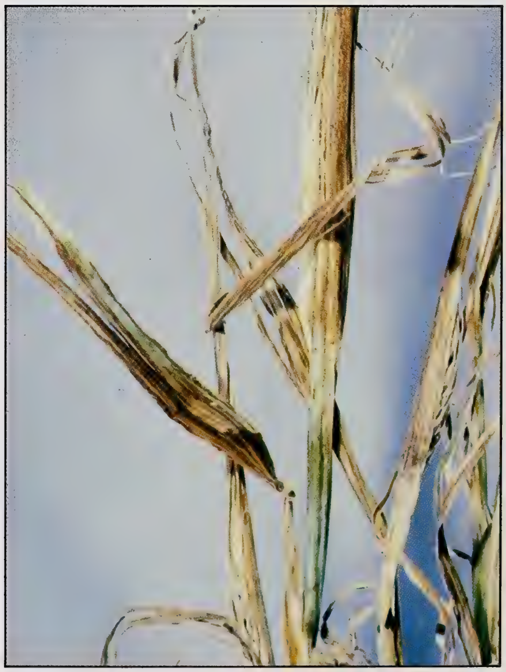

Figure 247

Figure 248

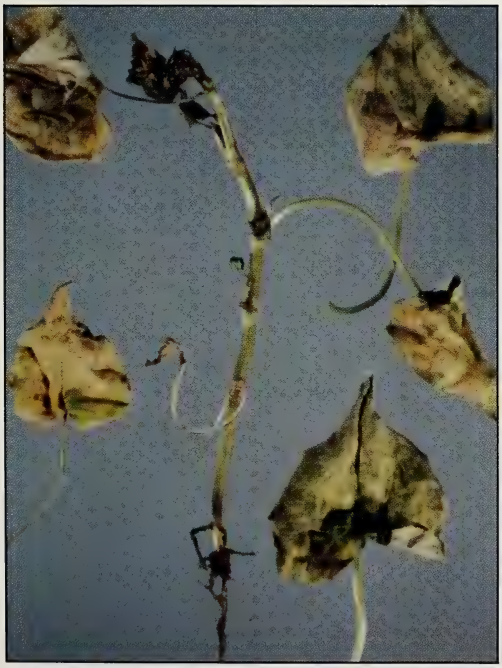

Figure 249

General uses

A relatively nonselective foliar-applied herbicide which is very effective on annual and deep-rooted perennial grassy and broadleaved species.

Symptoms in plants

Symptoms often develop relatively slowly under field conditions. The most common symptom is yellowing followed by browning. In some species leaves develop a yellow-orange color before complete chlorisis is evident. At relatively higher rates wilting is followed by mottling, browning and eventually plant death. At sublethal doses or in regrowth, leaf and stem deformities similar to those caused by growth-hormore herbicides 2,4-D, dicamba and picloram can occur.

Behavior and fate in plants

Readily absorbed by leaves and translocated throughout the plant. Inhibits photosynthesis and growth. Degradation in plants is very slow.

Behavior and fate in soil

Strongly adsorbed in most soils and unavailable to plants. Leaching is very limited. Losses from breakdown in sunlight and volatilization are negligible. Microbiological degradation is the major cause of disappearance in soil. Most crops can be planted soon after glyphosate application.

Effect on Weeds

Figures 248, 249, 250 and 251.

Wilting of glyphosate-treated plants occurs in five to ten days after application. This is followed by general overall yellowing and mottling, browning, and eventual plant death 10-20 days after application.


Figure 250


Figure 251

Figure 254

Figure 255

Figure 252

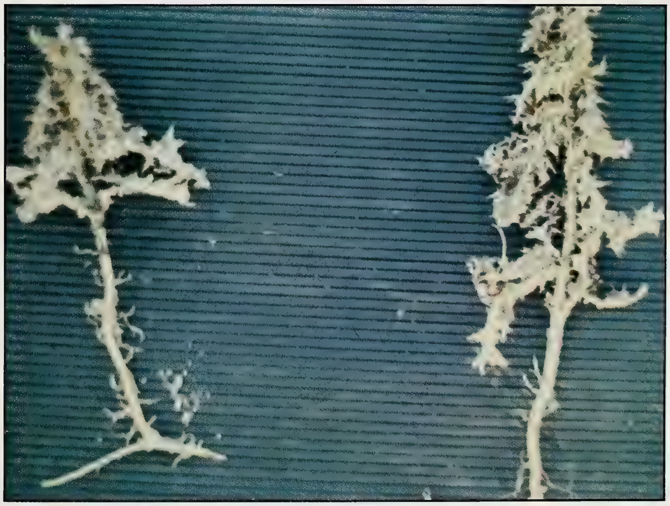

Figure 253

Figures 252 and 253.

The effectiveness of glyphosate on perennial weeds results from movement to and control of creeping roots, rhizomes and other underground plant parts.

Figures 254 and 255.

Sublethal doses of glyphosate can result in weak and yellow plants such as in red clover, or can produce leaf and stem deformities comparable to those caused by 2,4-D, dicamba, or picloram.

Glyphosate

Figure 256

Figure 257

Figure 258

Figure 259

Crop Injury

Figures 256, 257, 258 and 259.

Glyphosate drift during weed control operations can result in injury to all types of vegetation. Typical symptoms of such injury include chlorosis (yellowish orange) and browning on grassy species, chlorosis and cupping of newly emerged leaves in broadleaved species, and chlorosis of conifer needles.

Figure 260

Figure 261

Figures 260 and 261.

Although glyphosate residue is not generally a problem, wheat grown in soil treated with glyphosate at rates higher than those normally recommended may exhibit excessive tillering and some plant stunting. The growing point of a sunflower seedling first is yellow and then dies.

Glyphosate

Figure 262

Figure 262.

Glyphosate used for weed control adjacent to trees may be taken up by them and produce suckers showing leaf malformations similar to those caused by growth-hormore herbicides.

5. Sethoxydim

General uses

A selective postemergence herbicide for control of annual and perennial grassy weeds and volunteer cereals in broadleaved crops. Nearly 50 broadleaved crops are tolerant to this herbicide.

Symptoms in plants

The first symptom on susceptible species is cessation of growth usually within two to three days of application. Growing tissue in the nodes and buds become necrotic; young leaves show chlorosis then necrosis. The older leaves show yellowing, light purpling and finally browning. Affected plants are usually dead in two to four weeks.

Behavior and fate in plants

Absorbed rapidly by the leaves. Addition of an oil concentrate or other adjuvants enhances absorption. Readily translocated throughout the plant. Interferes with growth. Degraded rapidly in broadleaved plants.

Behavior and fate in soil

Broken down chemically in soil in the presence of either sunlight or water. Breakdown by soil microorganisms is rapid. Half life is 5-11 days in most soils under favorable soil and climatic conditions.

Sethoxydim

Effect on Grass Species

Figures 263 and 264.

Like fluazifop butyl the first symptom of sethoxydim, usually within two to three days of application, is a cessation of shoot growth of grassy species (weeds and crops). The young leaves show yellowing within a week. All broadleaved species are tolerant to sethoxydim.

Figure 263

Figure 264

Figure 265

Figure 266

Figure 267

Figures 265, 266, 267 and 268.

Later the older leaves also develop yellowing and then turn light purple (especially in corn) and brown. Affected plants are usually dead in three to four weeks.

Sethoxydim

Figure 268

Parallel Symptoms

Figure 269

Figure 269.

Phosphorous deficiency in barley can cause yellowing of older leaves that may look like sethoxydim damage from a distance. However, new leaves will not be yellow.